10/14-Lien

~~Confidential~~

CIA/OTI IR 97-134

(b)(1)
(b)(3)

Intelligence Report

Office of Transnational Issues *23 September 1997*

Assessing Opportunities in China's Market for Clean-Coal Technologies

China's dependence on coal to fuel its fast-growing economy raises serious environmental and health concerns.

- Respiratory disease from poor control of coal pollutants, for instance, is the leading cause of death in China, according to the World Health Organization.

- China's annual emissions of carbon--estimated at about 800 million metric tons--are second only to those of the United States, and with an expected growth rate more than four times the US level, China will have the world's largest carbon emissions by 2015, according to US Department of Energy projections.

So far, Beijing has done little to address air pollution problems, but if the Chinese decide to take more concrete steps, they do not have the domestic capability to manufacture clean-coal technologies such as fluidized-bed combustion, flue-gas desulfurization, and coal-gasification units.

- According to an industry study, the potential market for these technologies could be substantial--some $90 billion over the next 10 years.

A number of factors will determine if this sizable market materializes. China's current policy on foreign technology sales requires technology transfer, local production, and subsidized prices, which do not favor a market for expensive clean-coal technologies.

- **Moreover, enterprise reforms proposed at the recent 15th Party Congress mean that Chinese enterprises will have less capital to invest in technologies that are not associated with production.**

- **The poor financial condition of state-owned enterprises also makes it difficult for Chinese authorities to enforce environmental regulations.**

Prospects for a sizable market would improve significantly, however, if energy price subsidies were eliminated, prices were allowed to rise to market levels, and environmental laws were strictly enforced.

- **Under these conditions, Chinese consumers would be more conscious of the need for energy efficiency, and domestic suppliers would be in a better financial position to invest in clean-coal technologies.**

- **Beijing might then look for ways to improve plant efficiencies and apply clean-coal technologies in energy-intensive industries such as oil, chemicals, and steel.**

Key to gaining access to any Chinese market for clean-coal technology will be financing, especially offers of concessionary financing and direct aid. The Chinese also favor joint ventures to ensure long-term financial commitments.

- Companies from Japan, Germany, and France are formidable competitors of US firms, especially because they have a long history of using aggressive marketing tactics, such as concessionary financing, to win Chinese contracts,

Nonetheless the Chinese recognize that the United States has a clear technological advantage in nearly every clean-coal technology on the market today, and US firms have established a good track record for completing Chinese energy projects on time and within budget

- US companies also excel in less-sophisticated and costly technologies to improve plant efficiency, **and sales of these technologies could serve as a way to gain a foothold into China's larger market for clean-coal technologies.**

A Staggering Pollution Problem

China's heavy reliance on its abundant and cheap coal reserves to supply its fast-growing demand for energy has not only made China the world's largest coal consumer but has raised serious environmental and health concerns. Inefficient coal use and poor control of coal emissions are the root of serious air pollution and health problems in China.

- For example, ambient ground-level particulates and sulfur dioxide in China average more than five times World Health Organization (WHO) standards, and respiratory disease is the leading cause of death, according to the WHO.
- Moreover, according to official United Nations' statistics, China's annual emissions of carbon--estimated at about 800 million metric tons--are second only to those of the United States.
- The expected rate of growth in Chinese carbon emissions, however, is four times that of the United States and, by 2015, China will have the world's largest carbon emissions, according to US Department of Energy projections.

In an effort to address environmental problems, China in recent years has initiated what most industry observers characterize so far as a public relations campaign that boasts of ambitious plans to reduce air pollution. While some concrete steps have been taken to reduce harmful emissions and to improve coal-burning efficiency, these efforts have produced mixed results. The Chinese, for example, have promoted new technology to shape coal into briquettes for widespread residential and commercial cooking as well as the use of hot water district heating and town gas in major cities to limit coal use.[1]

- the increase in coal briquette production, which now accounts for about 30 percent of residential coal use, has been the most important development in reducing urban air pollution.

[1] District heating is the distribution of hot water (or low-pressure steam) to heat large urban apartments. The hot water is cogenerated (coproduced) with electricity at coal-fired power plants. Town gas is fuel gas produced from coke manufacturing used for residential cooking and heating. It was replaced by natural gas in most developed countries in the 1950s.

- Government projections for increased use of district heating and town gas, however, have not been achieved because of low, subsidized prices for these energy sources.

- In addition, an SO_2 emissions tax imposed on industries in southern China on a trial basis was low and not enforced,

- Beijing closed 60,000 "heavily polluting" industries last year, The factories, however, were small operations in rural locations and were not major polluters.

Beijing's current five-year plan allocates about $48 billion through 2000 for environmental protection and advocates development of noncoal energy sources such as hydro, nuclear, and natural gas, according to official Chinese press reports. China plans to rely heavily on advanced technology to meet its environmental goals.

- China wants to build state-of-the-art coal-fired plants as large and efficient as those in developed countries that have sophisticated emissions-control technology

- China might consider lowering tariffs on energy-efficient environmental equipment. An interministerial clean-coal technology group has been established to examine such tax preferences.

Huge Market Potential for Clean-Coal Technologies

China's coal use is growing at an annual rate of about 60 million metric tons. At this rate, an industry study predicts that China will have to invest $25 billion annually over the next 10 years to add new plants and equipment, and a quarter--or roughly $6 billion annually--will represent the market for clean-coal technologies. In that case, there also would be a large market for clean-coal technologies to replace existing coal use applications, especially in the industrial and residential/commercial sectors, representing another $3 billion annually over the next 10 years (see Table 1 and Figure 1.) The total clean-coal technology market amounts to at least $90 million. This assessment assumes that energy prices rise to free-market levels.

- There is a $3 billion annual market for coal-gasification units--the most expensive of coal technologies on the market. They represent a third of China's total market for clean-coal technologies. Coal-

Figure 1

Characteristics of Coal Technologies Most Appropriate for China

Sector Technology	Capital Cost	Operating Cost	Energy Efficiency	Emission Reduction Potential: Particulate	Emission Reduction Potential: SO_2	Emission Reduction Potential: NO_x	Emission Reduction Potential: CO_2	Comments
Industrial								Largest sectoral coal user in China, about 600 MMt/yr.
Cogeneration	●	◉	●	◉	◉	◉	●	Supplies both heat and electricity.
FBC[a]	●	◉	◉	◉	◉	◉	◉	Good for low-quality coal.
Gasification	●	◉	◉	●	●	●	◉	Allows superior engine-based cogeneration.
Residential								Sector uses about 200 Mmt/yr; high pollution per ton.
Briquettes	○	○	◉	◉	◉	◉	◉	Anthracite honeycomb briquettes most efficient.
Town Gas	●	◉	●	●	●	●	●	Enhanced by industrial/utility cogeneration.
Utility								Utilities use about 400 Mmt/yr coal.
PC[b]	◉	○	◉	○	○	○	◉	Installed on 300-600 MW domestic designs.
PC and FGD[c]	●	◉	○	●	◉	○	○	Favors low-cost designs with high-sulfur coal.
FBC	●	◉	◉	◉	◉	●	◉	Favors poor quality, low-sulfur coal.
CGCC[d]	●	◉	●	●	●	●	●	Allows superior trigeneration option.

○ Low
◉ Moderate
● High

a. Fluidized bed combustion.
b. Pulverized coal.
c. Pulverized coal and flue gas desulfurization.
d. Coal gasification combined cycle.

gasification units cost more than $200 million for a 1-million-ton per year plant. The market for coal-gasification plants and equipment would be even larger if town gas were produced with the cogeneration of heat and electricity.

- Fluidized-bed combustion (FBC) units represent another $2-billion-per-year market. FBC boilers substantially reduce both SO_2 and NO_x emissions and could be used by both the industrial sector and electric utilities.

- New and retrofitted plants with equipment designed primarily to limit emissions of fine particulates represent another $2-billion-per-year market. Although such equipment would be appropriate for all sectors of the economy, it would principally help replace direct coal combustion in the residential/commercial sector with increased production of town gas.

- Cogeneration systems--an estimated $2-billion-per-year market in China--hold great potential for China, especially in the industrial sector. Industrial growth currently is limited by electricity shortages, and there is a large unsatisfied need for both electricity and steam heat in China's energy-intensive industries.

Prospects for Market Penetration

A number of factors will determine if this sizable market materializes. Beijing's current policy on foreign technology sales requires technology transfer, local production, and subsidized prices, which do not favor a market for expensive clean-coal technologies.

- Moreover, enterprise reforms proposed at the recent 15th Party Congress mean that Chinese enterprises will have less capital to invest in technologies that are not associated with production.

- The poor financial condition of state-owned enterprises also makes it difficult for Chinese authorities to enforce environmental regulations.

Prospects for a sizable clean-coal technology market in China would improve significantly, however, if energy price subsidies were eliminated, prices were allowed to rise to market levels, and environmental laws were strictly enforced.

- Under these conditions, Chinese consumers would be more conscious of the need for energy efficiency, and domestic suppliers would be in a better financial position to invest in clean-coal technologies.

- Beijing might then look for ways to improve plant efficiencies and apply clean-coal technologies in energy-intensive industries such as oil, chemicals, and steel.

Key to gaining access to any Chinese market for clean-coal technology will be financing, especially offers of concessionary financing and direct aid. Moreover, Beijing has long been reluctant to buy foreign power and environmental equipment because of the cost and its desire to develop its own domestic industry. Senior Chinese officials have repeatedly emphasized that if foreign companies want to enter the power equipment market, generous financing, local production, and technology transfer must be part of the deal, according to official Chinese press reports. the Chinese are interested in "any environmentally friendly energy technology--regardless of its technical or economic merit--provided that concessionary financing is offered."

- The Chinese favor firms that have strong government support in the form of both direct and tied aid. For example, Japan's Green Aid Plan (GAP) is a government-sponsored program designed to provide developing countries with financing for environmentally friendly technology development, with the ultimate goal of increasing technology exports. The largest GAP-funded project to date involved the installation of desulfurization equipment at China's Huangdao Power Plant--a $60 million project. France has used tied aid that includes low interest rates and long grace periods in the past to help China develop nuclear energy.

- Firms that can provide expensive antipollution systems, such as flue-gas desulfurization (FGD) or FBC units, are considered only if there is special financing involved,

- China tries to secure financing from multilateral banks by adding particulate and nitrogen-oxide emission control units to plans. For example, in October the Asian Development Bank will consider financing half of a $300 million project to improve the environment in Shaanxi Province; the project includes expensive cogeneration and particulate-control equipment, according to press reports.

- The Chinese typically require joint ventures to ensure long-term financial commitment and improved prospects for technology transfer, but want to limit foreign firms to 50-percent equity participation,

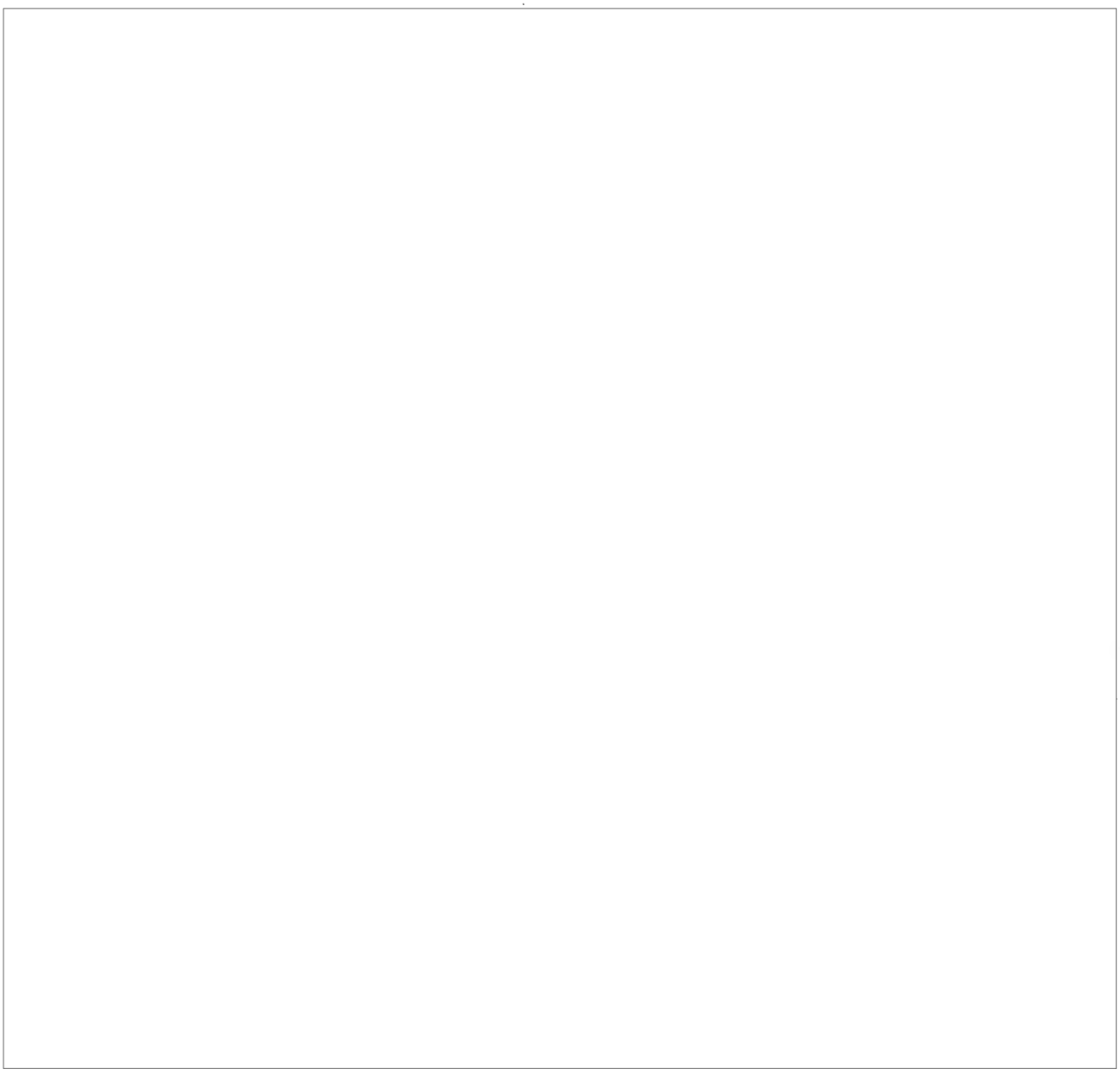
Western firms face other serious obstacles to market penetration. Among them are:

- *Inadequate rates of return.* Numerous press reports indicate that Beijing limits the rate of return foreign investors can earn on clean-coal projects to about 12 percent, which is too low to reflect the high risk of investing in China. US power plant financing--considered very low risk as compared with China--fetches an average 10-percent return. Such limitations on rates of return have stalled dozens of projects in the electric power sector, according to press reports.

- *Slow government approval process, stiff requirement for Chinese participation* the slow approval process and other bureaucratic bottlenecks have stalled dozens of proposals for clean-coal development. According to press reports, a senior official in the electric power sector said that, "without exception, all projects must be controlled by China." The announcement reportedly interrupted negotiations with several firms, including three US companies.

- *Subsidized energy prices.* Although there has been some minor energy price reform--especially in higher prices for town gas and electricity--the central government maintains strict control over energy prices. the market for clean-energy technologies will remain limited until energy prices accurately reflect the cost of production.

- *Corruption.* Corruption is rampant and "well-organized," and potential investors are expected to pay kickbacks to government officials on a regular basis to get approval for projects involving foreign energy technologies.



Opportunities for US Firms

The Chinese recognize that the United States has a clear technological advantage in nearly every clean-coal technology on the market, and several US companies have

[2] Synthesis gas is gas that is produced either by heating coal with high-temperature steam and an oxidant--air or oxygen--or by refining heavier hydrocarbons

established a good track record for completing projects on time and within budget in China,

- US companies have strong capabilities in the clean-coal technologies that have the greatest potential for China. For example, US firms that are considered world leaders in modern industrial coal gasification believe that China will need to make significant investment in power generation to avoid power shortages, and they see development as a way to steer the Chinese toward large-scale integrated gas, cogeneration plants as an alternative to more coal use. US firms also have an advantage over foreign competitors in FBC technologies.

Table 1

China: Annual Market for Clean-Coal Technologies and Processes, by Sector and by Technology/Application 1997-2008[1]

Sector	New Facilities (Billion US $)	Retrofit/Replacement (Billion US $)	Total (Billion US $)
Industrial	3.0	1.5	4.5
Electric Utilities	3.0	1.0	4.0
Residential/ Commercial	-0-	0.5	0.5
		TOTAL	9.0

By Technology & Application

Coal gasification	3.0
Cogeneration	2.0
Fluidized-bed Combustion	2.0
New emissions control	1.0
Retrofit emissions control	1.0
TOTAL	9.0

[1] Total market of $90 billion assumes energy prices allowed to rise to market levels.

Text Box
Appropriate Technologies for Reducing Pollution

, the most appropriate technologies to help China reduce air pollution vary by sector. Moreover, the effectiveness of these technologies in reducing sulfur, nitrogen oxide, and carbon dioxide emissions varies greatly, as do their costs (see Table 2.)

- The *industrial sector,* which consumes nearly 60 percent of China's coal production, according to industry reports, is China's largest source of air pollution, accounting for 40 percent of air emissions. the key to reducing industrial air pollution is to reduce particulate emissions from industrial boilers, especially those located in urban areas, by employing cogeneration, fluidized-bed combustion (FBC) or flue-gas desulfurization (FGD) units, or gasification technology.[3] Cogeneration--the production of heat and electricity from a single unit--can double the efficiency of coal use in large units, while FBC technology is most appropriate for small industrial boilers that burn high-sulfur coal. China gasifies only a small amount of coal per year--about 25 million tons of the 1.4 billion tons it produces.

- Coal-fired *electric utilities* account for about 40 percent of air pollution in China and consume about 30 percent of the country's total coal output. Although this sector's share of coal use is relatively small compared with the industrial sector, most foreign coal-technology suppliers concentrate on Chinese utilities because of China's ambitious plans to add about 500 gigawatts to its current generating capacity of 225 gigawatts between now and 2015, much of which will be coal-fired, according to industry reports. Typical of foreign technology offers are multimillion dollar 300- to 600-MW units with pulverized coal boilers, tall stacks, and particulate control. FGD units could help reduce ambient SO_2 air pollution, especially in the south where electric power plants utilize nearby high-sulfur coal as feedstock. Cogeneration and coal gasification are more expensive options to reduce air pollution levels in this sector.

- The major source of air pollution in China's *residential/commercial* sector, which accounts for about 20 percent of air emissions, is residential coal burning because of poor combustion efficiency, lack of particulate control, and short stacks. Continued improvements in

[3] See Appendices for a technical description of these technologies.

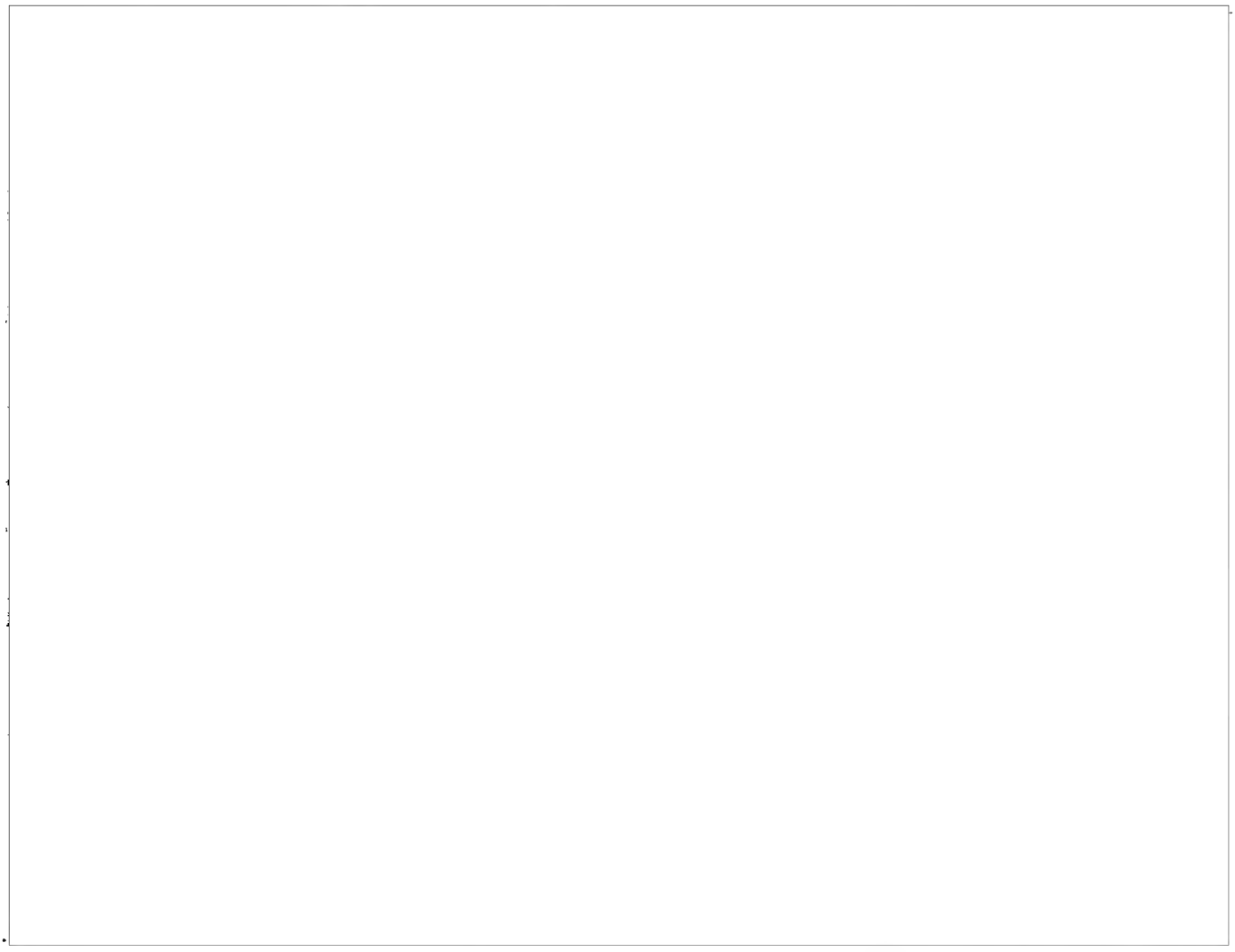
technology to form coal briquettes and an increase in the use of district heating and town gas would improve the situation. As was the case with the industrial sector, cogeneration and gasification technologies to produce town gas would also be effective in reducing emissions.

Table 2

China: Appropriate Coal Technologies/Improvements, by Sector

Technology/ Improvement	Industrial	Commercial/ Residential	Electric Utility
	Particulate control	Briquettes	Particulate control
	Plant Modernization	Cogeneration	Flue-gas desulfurization
	Cogeneration	Gasification (Town gas)	Plant Modernization
	Fluidized-bed Combustion	Coal Liquids	Cogeneration
	Gasification		Gasification

NOTE: Technologies or improvements under each sector are listed in order of increasing capital costs.



APPENDICES

A. Cogeneration

B. Fluidized Bed Combustion

C. Flue-Gas Desulfurization

D. Coal Gasification

APPENDIX A

COGENERATION

Cogeneration is the sequential recovery of electric and thermal energy from a single system. The principal advantage of a cogeneration system is the much-higher thermal efficiency achieved over cycles without heat recovery. Thermal energy can be recovered as hot water or warm air for space heating, or as steam for industrial purposes. A cogeneration system can be based either on a conventional steam cycle, such as one that might be used in a pulverized-coal plant, or on a combustion turbine-based cycle. In a conventional steam turbine cycle, thermal energy can be recovered either by withdrawing high-pressure steam produced by the boiler or by producing lower-pressure steam after expanding it in the steam turbine. The latter approach is the more common and efficient one. In a combustion turbine cogeneration system, thermal energy is recovered from hot turbine exhaust gas as high-pressure steam. The principal advantage of a combustion turbine-based cogeneration system is that electricity output is not affected by the level of thermal recovery. In a steam turbine-based system, electric power is directly reduced by the amount and pressure of steam that is not expanded to a vacuum, low-temperature condensing condition.

APPENDIX B

FLUIDIZED-BED COMBUSTION

Fluidized-bed combustion (FBC) is a technology in which coal is burned in a bed of granulated particles that are maintained in a mobile suspension by the upward flow of air and combustion products. In FBC, SO_2 and NO_x emissions are reduced by controlling combustion parameters and by injecting a sorbent (such as crushed limestone) into the combustion chamber along with the coal.

In the FBC process, pulverized coal mixed with crushed limestone is suspended (or fluidized) on jets of air in the combustion chamber. Sulfur released as the coal burns is captured by the limestone before it can escape from the boiler. This sulfur chemically combines with the limestone to form a new solid waste product, a mixture of calcium sulfite and calcium sulfate. Some of the solid waste is removed with the bed ash through the bottom of the boiler. Small ash particles (or fly ash) that escape the boiler are captured with dust collectors (such as cyclones, baghouses, electrostatic precipitators, or ceramic filters). More than 90 percent of the sulfur released from coal combustion via FBC can be captured in this manner.

FBC typically occurs at combustion temperatures of 1,400-1,600° F. In this temperature range, the fluidized mixing of the coal and sorbent enhances both coal combustion and sulfur capture. The operating temperature range is almost half the temperature of a conventional stoker boiler and is below the threshold where thermally-induced NO_x is formed. FBC has the capability of utilizing high-ash coal, while conventional PC units burn lower-ash fuels. An ideal application of FBC technology is for burning coal-cleaning plant solid waste. This avoids most of the coal-cleaning energy losses and serious pollution problems.

APPENDIX C

FLUE-GAS DESULFURIZATION

Flue-gas desulfurizaiton (FGD) has become the conventional technology for control of SO_2 emissions from pulverized-coal power plants. FGD is a postcombustion method removing sulfur compounds from the downstream flue gas after it exists the boiler. FGD technology is well-tested and diverse, with over 100 processes developed since the 1960s. It is widely used, especially in the United States and Japan. The basic approaches to FGD include:

- Wet FGD scrubbing processes. A reagent (lime or limestone) is used to capture SO_2 in the flue gas in a nonregenerable (or throwaway) method (producing a solid waste or marketable byproducts such as gypsum) or a regenerable method (producing sulfur, SO_2, or sulfuric acid.)

- Sorbent injection FGD scrubbing processes. Sorbents are injected into the flue gas in the existing ductwork (in-duct sorbent injection) or in separate downstream ductwork.

- Spray-dry FGD scrubbing processes. A slurry of an alkali chemical (such as sodium or calcium) is sprayed into the flue-gas stream and the hot flue gas evaporates all the water in the slurry, leaving a fine powder of sulfite or sulfate salts of calcium or sodium.

FGD technology is suitable for both new and retrofit facilities. Depending on the process selected, up to 95 percent of SO_2 can be removed via FGD scrubbing. Other advantages of FGD technology include its reduced waste generation of dry, benign waste products or marketable byproducts and its high reliability and availability, which reduces the need for spare capacity.

APPENDIX D

COAL GASIFICATION

Coal gasification is a process for converting the solid fuel into combustible fuel gas via partial combustion. The process generates synthesis gas by reacting coal with high-temperature steam and an oxidant (oxygen or air.) When the oxidant is air, low-British Thermal Unit (Btu) syngas is produced, which can only be used locally to fire boilers, gas turbines, and industrial furnaces. When the oxidant is oxygen, a medium-Btu syngas is produced which can be used locally as fuel or transported to industrial or commercial customers for further use. Syngas can also be further converted to a highly pure mixture of CO and H_2, and be used as feedstock for the production of ammonia, methanol, hydrogen, and other high-value chemicals. Coal gasification economics generally favor the use of oxygen over air and high-pressure operation.

There are numerous coal-gasification processes with different design features. However, essentially every gasification process requires one of three classic (or generic) reactor types--moving-bed (or countercurrent), fluidized-bed (or back-mixed), and entrained-flow (or plug-flow) gasifiers. Some design parameters that are important to the choice of a specific process include:

- The size of pulverized coal used in moving-bed gasifiers.
- The way in which coal is fed to high-pressure gasifiers.
- Gasifier operating characteristics, such as temperature (1,000-2,600°F), steam, and oxygen requirements.

Coal gasification is the most efficient coal technology of choice relative to SO_2 and NO_x emissions control. Sulfur removal is greater than 98 percent, and the sulfur is recovered as liquid elemental sulfur, a salable commodity. NO_x emissions (before postcombustion removal) are also much lower than with other coal technologies. Other advantages of coal gasification include its recovery of high-value-added byproducts, use for production of cogenerated power, potential use for phased capacity addition, and the ability to be used to repower old coal-fired power plants.